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Eco-Retrofitting

From Managerialism to Design

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Abstract

As all environmental problems are caused by human systems of design, sustainability can be seen as a design problem. Given the massive energy and material flows through the built environment, sustainability simply cannot be achieved without the re-design of our urban areas. 'Eco-retrofitting', as used here, means modifying buildings and/or urban areas to create net positive social and environmental impacts – both on site and off site. While this has probably not been achieved anywhere as yet, myriad but untapped eco-solutions are already available which could be up-scaled to the urban level. It is now well established that eco-retrofitting buildings and cities with appropriate design technology can pay for itself through lower health costs, productivity increases and resource savings. Good design would also mean happier human and ecological communities at a much lower cost over time. In fact, good design could increase life quality and the life support services of nature while creating sustainable 'economic' growth. The impediments are largely institutional and intellectual, which can be encapsulated in the term 'managerial'. There are, however, also systems design solutions to the managerial obstacles that seem to be stalling the transition to sustainable systems designs. Given the sustainability imperative, then, why is the adoption of better management systems so slow?

The ***oral*** presentation will show examples of ways in which built environment design can create environments that not only reduce the ongoing damage of past design, but could theoretically generate net positive social and ecological outcomes over their life cycle. These illustrations show that eco-retrofitting could cost society less than doing nothing - especially given the ongoing renovations of buildings - but for managerial hurdles. The ***paper*** outlines on how traditional managerial approaches stand in the way of 'design for ecosystem services', and list some management solutions that have long been identified, but are not yet widely adopted. Given the pervasive nature of these impediments and their alternatives, they are presented by way of examples. A sampling of eco-retrofitting solutions are also listed to show that eco-retrofitting is a win-win-win solution that stands ready to be implemented by people having management skills and/or positions of influence.

Paper

1. Need for eco-retrofitting

It is first necessary to review the need for eco-retrofitting (developed in more detail elsewhere).[1] Existing cities account for about three fourths of greenhouse gas emissions, and forty percent of ongoing material and energy flows. Yet humans have already exceeded the Earth's carrying capacity.[2] Sustainability cannot therefore be achieved by leaving things as they are, or replacing existing buildings with new green ones, due to the amount of material flows, embodied waste, and ecological damage this would entail. Moreover, given that only about two percent of the building stock is new each year, new green buildings do little to reduce the growing rate of greenhouse emissions and energy consumption generated by conventional built environment design. Sustainability will require built environments that create the range of meaningful - yet responsible – life choices for everyone (including habitat for other species and biotic communities). To achieve this, systems resilience, restoration and remediation will not be enough. Ecological sustainability will require increasing the *total* amount of urban ecosystem goods and services, and ecological carrying capacity, so that cities support the integrity and health of the bioregion's ecosystems. This means eco-retrofitting the built environment and urban landscapes to create the infrastructure, conditions and space for nature to continue its life-support services and self-maintenance functions.

Managerial approaches are those that encourage business and/or the community to reduce relative impacts through market-based and/or regulatory 'incentives' such reporting, rating and labelling mechanisms. These tend to create ever more compliance activity and transaction costs. Moreover, building rating tools and assessment processes have focused on predicting, measuring and mitigating the *future* negative impacts of conventional designs. Measuring is constructive if we measure the right things, but our environmental management processes and tools are not designed to assess, let alone generate, eco-positive design. Since environmental problems are caused by poor systems design, they can be corrected by eco-logically sound design. In fact, the transformation to sustainable systems - those with net positive ecological, social and economic impacts - can *only* occur by design. This is because negative impacts are *designed into* our built environments and their tributary industries. Apart from pollution and environmental degradation, the design of development has led to increased floods, droughts, fires, excessive urban heat and storms. The damage these 'acts of god' cause, and even the deaths from cyclones and earthquakes, can be prevented or reduced by design.

To achieve eco-positive development, management and decision making methods will need to actively promote 'design for ecosystem services'.[3] The ecosystem goods and services of nature include: (a) producing crops and natural fertilizers; (b) heating, cooling and ventilating using the sun; (c) preventing soil erosion and sediment loss; (d) purifying water and air; (e) restoring and recycling fresh water and nutrients; (f) regulating the chemistry of the atmosphere; (g) maintaining habitats for wildlife; (h) alleviating floods and managing storm water runoff; (i) disposing of organic wastes; (j) sequestering carbon; (k) controlling pests and diseases; (l) producing food, fibres, pharmaceuticals; (m) producing healthy construction materials; (n) regulating the local and global climate; (o) developing topsoil and maintaining soil fertility; (p) protecting against UV radiation, etc. To implement 'design for ecosystem services', management systems are needed that are compatible with the needs of the life support system and supportive of creative design approaches. The aim of management systems should be to facilitate rapid biophysical, institutional and intellectual *design* that increases the quality of life and life support system in absolute terms.

One of the biggest areas that need an institutional and intellectual re-think, in order for this paradigm shift from negative to positive to occur, is management itself. While leading-edge management appreciates the importance of design - as indicated by Global Forum 2009 - environmental management is still largely dominated by the twin ideologies of 'prediction-control' and 'incremental-adaptive'. Both approaches reflect the obvious proposition that to survive in the modern world, management and decision systems need to deal with complexity. However, both lead to planning and policy strategies that are inherently evasive, manipulative of, or reactive to, existing systems. Still in the minority are management philosophies that recognize that our social inequities and environment problems are by design – not due to nature or the 'nature of man'. Some of our industrial systems were imposed and some evolved, but both inter-twined processes took hold because they met the needs of some at the expense of nature (and other people). Now that the earth's geographic and resource limits are no longer beyond the visible horizon, people are beginning to accept competitive relationships as social constructions. If inequitable resource transfer systems are *not* pre-ordained, they need to be re-conceived.

Once management responsibility for system outcomes is recognized, the challenge becomes to design management systems and tools that do *more* than make the system work better for the immediate stakeholders (ie individuals, organizations or firm with vested interests). The challenge is designing systems that have net positive outcomes for society, nature and the economy. The view that power relationships are inevitable because of a competition for resources is beginning to give way to a new *design* approach that creates more cooperative and creative relationships. Improving human and ecosystem health, while reducing net resource depletion, greenhouse emissions, land degradation and so on, implies an integrated and eco-logical design approach - not just 'adding on' energy and water saving equipment. It also implies a planning strategy that considers whole suburbs, cities, infrastructure and bioregions.

The purported economic benefits of eco-retrofitting - increased work productivity, resource savings and health benefits - have already been widely canvassed in the literature.[4] However, although renovations in some regions account for about a third of construction activity or more, little of this is undertaken with sustainability in mind. From a whole systems perspective, eco-retrofitting costs far less than traditional toxic renovations. In fact, conventional building renovation and demolition waste can account for over ninety percent of (often) toxic construction debris each year. Eco-retrofitting is an *essential* component of a sustainable society, yet most green building management processes and tools are still geared toward new construction. Eco-retrofitting programs continued to be postponed by government inertia, and industry uptake has been slow in relation to conventional renovation projects. Meanwhile, delegated managerial activity proliferates.

We now know that buildings can be retrofitted to restore and remediate urban environments, and produce clean energy, water, air and soil.[5] But eco-retrofitting for Positive Development would go further. 'Positive Development' is about creating new syntheses, synergies and symbioses that generate healthier environments and systems for all natural ecosystems and human interests than existed before settlement.[6] Cities would be re-designed to be eco-productive, but also to increase the region's ecological carrying capacity, provide more ecosystem services, and support appropriate biodiversity habitat and nature corridors. That is, eco-retrofitting could increase sustainability in absolute terms, not just increase the relative efficiency of new buildings.[7]

This paper lists some *solutions* to obstacles that have largely been ignored. Then it lists some random examples of *eco-solutions* that use natural systems, radically reduce resources and/or provide the infrastructure for ecosystem services.

2. Managerial impediments to design solutions

Despite a large variety of ways to measure some of the negative impacts of development (by drawing boundaries to exclude what is difficult to measure), few management processes and tools contemplate, let alone encourage, eco-positive impacts. The focus has been on developing competing forms of numerological charts - instead of management systems that encourage design solutions that recognize the site-specific needs of ecosystems and communities, as reflected in the following categories.

Direct action: Whether global warming is man-made or not - or whether it not exists - is, for practical purposes, almost irrelevant. The fossil fuel supply chain is harmful at each stage of development and distribution. Even small eco-retrofitting projects have the potential to stimulate systems-wide changes to passive solar energy. Eco-retrofitting could be undertaken rapidly, through what Jaime Lerner of Curitiba calls 'urban acupuncture' (ie urban ecological gentrification). However, the transition to low carbon cities has been delayed by debates over global warming and insistence on ideologically-based approaches (like carbon trading). These supplant net positive action with indirect displacement activity. Direct design solutions can pay for themselves, whereas complex managerialist systems for mitigating the impacts of fossil fuels cannot.

Exemplars: There is a lack of eco-retrofitting 'demonstration projects' that show people how sustainable design can provide more quality of life with less negative environmental, economic and social costs.[8] Those that exist tend to only aim to reduce energy, pollution and waste. The management philosophy in the built environment sector in relation to sustainable design is apparently 'be second, not first'. Innovative exemplars would help to address the lack of public awareness of the issues and potential solutions among all sectors that influence the built environment: clients, builders, government, designers, tenants, etc. Exemplars could also counter the stereotype that passive solar or responsible design is stylistically 'boring'. However, the far more popular approach is to target improvements to *new* suburban homes by making them slightly more efficient, based on allusions to the untested conviction that the market does not 'demand' truly sustainable homes.

Verification: To date, rating tools are the dominant management approach to improving resource efficiency in the built environment. Based on conventional buildings, these tools encourage measures that massage an unsustainable prototype, rather than encourage a paradigm shift to a more sustainable architecture. Green building developers have to pay large sums for green certification, while bad design is not penalized, or even labelled as harmful to the environment. Some buildings awarded high ratings have since proven to perform poorly. There has been reluctance on the part of those awarded certification - which is based on prediction - to open their books later to see if performance lives up to the rating.

Measurement: The management axiom that 'we cannot manage what we cannot measure' suggests that management has not really come to terms with complexity, let alone ecology. It is virtually impossible to measure negative impacts due to the interaction of thousands of introduced chemicals in the environment, the sensitivity and variability of immune systems, bioaccumulation of toxins, and complex interactions between species and ecosystems. On the other hand, it would be easy to measure positive impacts (eg soil biota, clean air and water). Measuring, mitigating, and monitoring might be useful if we measured the right things, but despite a large variety of ways to measure some of the negative impacts of development, few tools encourage eco-positive impacts.

Market myths: The market value of eco-retrofitting homes more than pays for any additional up-front costs.[9] There are means to overcome the outdated misconception that 'retrofitting costs too much'. Moreover, mechanisms have long been available to offset the up-front design costs of better buildings through the long-term economic benefits of resource savings. These include 'performance contracting', where the retrofitting contractor is paid from the energy savings. This means that the client need not pay anything for a more energy efficient home which saves them money. In Australia, after many years of encouragement, government funding has gone into studying the likely reaction of consumers to a green loans program for retrofitting - which could have been spent on funding more eco-retrofitting directly. In the USA, in contrast, homes of families that could not afford insulation were 'weatherized' for a net public savings over time.

Eco-design reporting: The focus of planning and environmental management has been on measuring, monitoring and mitigating a design after it is conceived. Complex environmental impact assessments and rating tools predict and quantify relative negative impacts at great expense, but do not acknowledge the value of ecosystem services. Mechanisms that would drive continuous learning in ecological design, research and development and reduce the huge investment in numerological forecasting have not been adopted. One is Eco-design Reporting.[10] The process would shift the burden of proof and require an explanation of why net Positive Development was not achieved in the particular instance. This would drive self-education and inquiry in ecological design, rather than creative writing and book-keeping.

Incentives: Regulations and incentives to encourage new eco-efficient products, services or processes are inadequate to counteract the inertia of business-as-usual or to create a level playing field. The managerial approach has been to set up expensive certification and labelling programs, which create jobs for consultants (not designers), but do not eliminate poor environmental performers from the market. For example, imported air conditioners in Australia from some other countries have made false claims about their efficiency. Historically, non-government organizations (NGOs) have had to serve as watchdogs. For example, although indoor air quality is one of the biggest health problems and exacerbates many other illnesses,[11] healthy materials have to rely on market-based mechanism like certification and labelling originating from NGOs. In contrast, lead-based petrol was simply phased out, albeit slowly.

Partnering: Building industry management is still characterized by fragmentation, segregation and adversarial processes throughout the long and intricate supply chain. It has long be recognized that oppositional structural relationships among designers, builders and owners lead to zero sum games. For example, there has been an incentive to charge extra for change orders, which is a popular way of making a profit after bidding low to get the job in the first place. 'Partnering' has been around for a long time but has still not been widely adopted. It involves the stakeholders working together to share risks and rewards, and has been proven to be effective and economical for all parties.

Life cycle planning: Good management would try to leverage the whole supply chain to adopt green practices. Despite more than ample rhetoric, however, the uptake of *integrated* design, construction, commissioning and management processes has been slow. Most developers still do not to worry about the life cycle costs of the components (products, materials and equipment), or the building's environmental performance after it is off-loaded. A design or building is only as good as its weakest link. For example, errors that permit mould to grow can eventually destroy a whole building. Tools based on life cycle assessment are still designed to optimize negative impacts through component selection, not to generate positive impacts through whole systems design.

Procurement and stewardship: Procurement systems to ensure building components are green and 'appropriately' durable have been advocated for decades. In the meantime, people in China and India continue to recycle the toxic metals in out-dated electronic products, called e-waste, for slave wages and shortened lifespans. Product Stewardship Australia (PSA) is one example of a not-for-profit organization that aims to recover and recycle electronic and electrical products in an environmentally sound manner. PSA reputedly now represents about sixty percent of televisions supplied into the Australian market.[12] By providing this service and others, such as repairs, profits can be made while reducing toxic waste.

Bias toward new building: The reliance on reductionist and prescriptive building codes, and assessment and rating tools, favours new construction over retrofitting, and fail to consider the ongoing costs of existing development generally. Cultural attitudes favour new buildings, such as the belief that design itself is an added luxury when, in fact, it is a miniscule portion of the cost in the total life cycle of the building - estimated at one percent. Construction itself is only about ten percent of the total life cycle cost of a building. These attitudes co-evolved with a tradition of subsidies that favour non-renewable resources (eg fossil fuels reportedly receive nine billion dollars in subsidies in Australia each year). This enables highly *inefficient* new buildings to be built and old buildings to continue to operate without improvements.

Recycling networks: On average, overall consumption of materials in the USA has doubled every 20 years during the 20th Century.[13] There are practical difficulties in recycling building materials, of course. For example, delays in a scheduled de-construction nearby could throw off the timing of a new construction or retrofit and thus end up costing extra time and money. Databases for recycling building materials have been created to link people needing materials with people de-constructing buildings, who would otherwise pay for waste removal. That is, the internet allows for linkages between materials and specific geographic areas that are timely as well as competitive. This would enable retrofitting projects to be designed around available materials. Extensive data has been collected on toxins from factories, but not on toxins embedded in the built environment. Asbestos could be embalmed in retrofits rather than transported to landfill.

Credit schemes: Carbon credit schemes have thus far given credits for doing less damage, and thus do not represent a sustainable management system. Private firms are beginning to develop their own forms of credit schemes. EnviroGLAS, a company that turns recycled glass into flooring and other products, offers to be part of the construction waste demolition team in demolition projects. They remove and reclaim glass that is to be recycled and re-makes it into new glass products in return for a crediting scheme. (Such systems may be required as nearly seventy five percent of all glass bottles made every year end up in landfill - despite recycling schemes.)[14] However, little has been done to assist public or private trading schemes that encourage net positive impacts.

Cooperatives: Transaction costs are one of the biggest barriers to recycling or upcycling to a higher use. Gerry Gillespie, Zero Waste Australia, is developing a 'soil cooperative' where the farmer/collector/processor forms a single contractual identity, so the material collection and processing can be paid for up-front by those using the waste. The compost product would be transported to the land, where it would be made into a range of solid or fluid products – modified to agronomic standards, depending on local soil and crop applications. Humic compound levels correspond to carbon sequestration, so they could be registered by the soil cooperative even before application for carbon credits.[15] This could evolve into a net positive trading scheme.

Pre-cycling: Insurance premiums could reduce the risk of products becoming waste. 'Precycling', proposed by James Greyson, would mean charging producers insurance premiums in proportion to their waste-risk.[16] This generalizes the 'recycling insurance' enacted by the European Waste Electronics Directive, which funds recycling to cut the risk of particular products becoming waste. A generalized 'precycling insurance' fund could support the full range of sustainable development activities. The incentive of avoiding premiums would support producer investment in systems which avoid waste or ensure product stewardship over its lifecycle.

Eco-specifying: Good Environmental Choice Australia and Ecospecifier are Australian examples of management tools that have been developed to help those working in the built environment to source products and materials which are better for the environment than standard ones.[17] They test innovative products that represent a higher value over their life time than conventional ones. However, the fees to have products evaluated are high and institutional buyers do not always trust new products anyway. Certification also tends to favor existing products over innovation in site-specific *passive* design. Many managers prefer to buy things off the shelf than hire designers trained to look at whole systems.

In other words, solutions have been around, but have been largely advocated by environmental groups, not managers in government or industry (with some famous exceptions). Industry's response has been to establish 'self-regulation' and reporting tools to side-step threats of government and/or community sector programs, processes or regulations. This means more managerial activity, like reporting, rather than the implementation of immediate design solutions. Management is positioned to elevate 'design for ecosystem services' to its rightful place along side 'linear-reductionist' problem solving. This would enable us to shift from zero-sum competitive approaches toward net Positive Development.

3. Eco-retrofitting resources

As explained above, ecosystem services are natural systems that provide life support services for humans (heating, cooling, food, waste treatment, etc). They can utilized in built environment design at little or no operational cost if adequately supported by design. There are many eco-solutions that radically reduce resource consumption, and/or provide the infrastructure for ecosystem services to function on their own, while making the built environment more healthy and secure.[18] The following is only a random sampling of such design concepts and technologies that could be applied to eco-retrofitting at a building or city scale. Many are applicable for new construction as well.

It is important to note that these ideas are *not* being advocated. They are presented to represent the wide range of resources that could be combined in eco-retrofitting projects.

3.1 Toxin removal

Natural systems are self-managing, self-organizing, self-perpetuating, and collectively act to decontaminate the air, water and soil, increase biota and expand biodiversity. For example, microbes and earth worms can convert contaminated land into fertile soil, bio-solvents of vegetable are often used to clean up oil spills, and reed beds can treat water pollution.

Mushrooms: Non-toxic insecticides from mushrooms can replace harmful agricultural and domestic poisons.[19] Mushrooms transform some toxins chemically so that they are still safe to eat. Their mycofiltration properties aid in the purification of water and increase oxygen. Mycelium membranes (mushrooms) can be integrated with planting walls to reduce air pollution. They have also been used to regenerate old forest roads to reduce erosion.

Glass that expels CO2: Living glass can ventilate a sealed room.[20] The 'glass' is a thin material that is linked to sensors which detect the lack of carbon dioxide. The wires laid out within the surface react by contracting, thus opening the 'slits' in the window to release carbon dioxide outside the room. This air can then be processed through plants to absorb the CO2.

Cork: One can add a VOC-removing material, such as cork that contains micro-organisms found in natural soils, along with plant nutrients, spores and seeds.[21] Planting walls (below) can cover existing interior walls which off-gas paint by-products. The cork wall can become part of a living environment (of moss, ferns, creepers and epiphytes) that seals off existing harmful materials such as asbestos that would otherwise leach from landfill.

3.2 Materials

Conventional building materials contain VOCs, solvents, formaldehyde, etc. Compostable, non-toxic, bio-based materials are generally much healthier. The can be produced on farms in the region to help to diversify agricultural production and revitalize rural communities.[22] Of course, their relative life cycle impacts depend on how and where the agricultural materials are farmed and the total resource flows and toxins involved in their production.

Edible plates: Some designers, such as Japanese designer Nobuhiko Arika have made edible tableware.[23] This tableware is made from biscuit dough, but they can be made from rice or other edible materials. After a dinner that is grown on site (below), plates can be eaten for desert, or composted, rather than washed.

Hemp: Hemp is a hardy plant that requires less water and fertilizer than similar crops. It can be used to replace any plastic that is composed of petrochemicals (fossil fuels).[24] It has both high thermal mass and good insulation (a rarity in building materials). It can be poured like concrete or as fluffy insulation. Whole houses have been made from Hemp.

Silica Aerogel: High levels mould from damp, poorly ventilated building materials can cause serious health problems.[25] This is a huge financial problem in San Francisco and Auckland. Silica Aerogel is a low-density, solid state material that not only can absorb nearby moisture particles but can also serve as a highly effective thermal insulator. It could be adapted for use in the building and construction industry.

Biodegradable products: Biodegradable materials consume less energy in their production and are easier to dispose of at the end of their useful life. For example, some shoe companies are moving toward biodegradable materials in the design of their shoes.[26] Biodegradable materials are only sustainable if they are sourced from sustainable farming methods.

3.3 Recycling

Waste can be greatly reduced by design. Recycling turns waste into products, jobs and resource savings. While recycling usually means 'down-cycling' to lower-value products, and entails waste in the process, clever design could contribute positively to the environment, by turning waste into resources that produce only healthy and necessary products. In the meantime, waste generation has continued to increase, due to the disposability, excessive packaging, after sales maintenance, and constantly updated technology.

Office pens: Plastic pens have a high throw-out-rate, but *Din-ink* turns office tools into common cutlery.[27] Designed by Andrea Cingoli, this pack includes a fork, knife and spoon-caps that replace a normal pen cap. The caps are made from non-toxic renewable resources, like natural starch and fibers, and are 100% biodegradable in 180 days.

Furniture from waste: Outdoor furniture has been made form used CDs, baseball bats and skateboards. Quality timber furniture has been produced from old shipping pallets. Dutch designer Tejo Remy has designed seats fashioned from a steel frame and dozens of tennis balls not deemed suitable for sale.[28]

Shipping containers: There are dozens of examples around the world where used large shipping containers have be modified, connected and stacked to create office and home spaces for a fraction of the cost, labor, and resources of more conventional materials.[29] These range from little cabins to large residential or office structures.

3.4 Climate mitigation

Plants absorb Carbon Dioxide and produce oxygen, yet we have historically excluded them from the built environment - except where the serve only decorative purposes. The whole system benefits of forests have been forgotten in the recent emphasis on carbon sequestration. Deforestation is nominally held responsible for only 25% of climate change forests, but they are a core part of a complex, self-adjusting feedback mechanism that regulates climate.

Urban trees and green roofs: Particulates are a significant cause of lung disease.[30] Tree-lined streets have only 10-15% of the dust found on similar streets without trees. Green roofs and walls can mitigate the heat sink effect. They also cause urban air to *circulate* as well as helping to clean the air. Urban Ecosystems in Spain have proposed an 'air tree' to improve urban microclimatic conditions.[31] It is a free standing round scaffolding for plants and trees. It is similar to green scaffolding, which would wrap an older building in an ecosystem to provide multiple ecosystem services and environmental amenity.[32]

C02 absorbent concrete: Olivine (a green-coloured mineral) is reputedly capable of absorbing, over its life, ten times more CO_2 from the air than the CO_2 that is emitted during concrete production.[33] It is used in open (very porous) concrete in which sand and gravel have been replaced by Olivine. Similarly, Tec Eco cement integrates reactive Magnesia (Magnesium Oxide) and sequesters wastes.[34] This also entails lower embodied energy and CO_2 in production by using Magnesite instead of limestone (calcium carbonate).

Permeable pavement: Water systems are degraded by high temperature run off. Cool pavement has the ability to absorb water, reduce storm water runoff and improve the environmental quality of water systems by filtering pollutants.[35] Grasscrete, for example, is an alternative to car park paving. It forms part of a natural bio-filter that removes pollutants, and reduces clay sub-soil shrinkage and instability in building foundations.

3.5 Soils

Australia is soil poor, and desertification is increasing around the world. However, compost can be produced and delivered to the farm gate cheaper than to landfill.[36] As space for agricultural production and soil productivity is depleting, growing food in cities will become more economical. Abandoned multi-level structures can be retrofitted for indoor farming, for which compost and nutrients can be sourced locally from nearby residents.

Vertical composting: Free standing or building integrated vertical composters save space. Some high-density residential areas in the UK have used 'vacuum waste collectors' which reduce the need for garbage trucks and their associated damage.[37] Vacuum waste collectors on the roof of residential buildings suck food scraps down ducts into a collection area where it can be applied to a shared garden.

Solar ponds: Salinated land can be reclaimed while producing salt and heat as by-products. 'Solar ponds' are salt ponds that collect and store solar energy.[38] Heat builds up at bottom of 2-3 metre deep salt pond. It is not able to escape as the heated water is denser due to the concentration of salt. Heat from the solar pond can then be used to dry the salt, brine shrimp or produce space heating.

Bio-char: Carbon sequestration can be combined with reforestation and land regeneration. Bio-char (charcoal created by biomass and pyrolysis) can be buried in with soils.[39] This creates organic matter which improves the soil and water quality through the process of filtering. Phytoliths (plant stones) and bio-char can provide a measurable basis for allocating carbon credits to farms.

3.6 Food

With 50% of the world's populations living in cities, damaging industrial farming practices, a projected three billion increase in the human population by 2050, and the resultant destruction of millions of hectares of forests. Vertical farming may become a necessity, whether costly or not. However, food production using closed loop systems can be combined with walls, furniture, alleys or abandoned warehouses.

Urban agriculture: A wide variety of produce can be harvested in quantities large enough to sustain large cities without relying on significant resources beyond the city limits. One proposal, by Disponnier of Columbia University, would house 3 million square feet of hydroponically grown produce to feed 10 thousand people per day.[40] Currently fisheries are detrimental to ocean habitats.[41] Acquaponics is a vertical food production system where fish poo provides the nutrients for the ecosystems that produce the fish food.

Dog waste composters: Pet waste can be placed in a special container where the worms and enzymes break it down to a liquid that is not harmful to local plants. These containers can be sited in city parks and dog runs. The 'Doggie Poo Pet Waste Eliminator', is simply an organic bag which enables composting with or without these composters.[42]

Biosphere home farming: This internal food production is a closed loop system which produces food and cooking gas, while filtering water and absorbing CO_2. It incorporates a methane digester that produces heat and gas to power lights, while algae produces hydrogen, and the root plants produce oxygen (which is fed back to fish). The system uses waste water and non-consumable household matter and reputedly delivers several hundred calories a day in the form of fish, root vegetables and plants.[43]

3.7 Air cleaning

Placing an indoor plant every 100 square feet can reduce indoor air pollution by 87%, according to NASA. An average 1,800 square foot house, would need around 17 good-sized plants in 6 – 8 inch diameter containers in order to see a notable difference in air quality.[44] However, if one has little space, planters can easily be supported by the wall or ceiling. Garden environments do not require more maintenance in relation to health benefits than fossil fuel equipment.

Vertical gardens: Hanging landscapes take up little space and can treat water through a series of attractive containers.[45] Frames that hold the water reservoir, plants, soil and irrigation system are available that can be hung on walls like a cupboard.[46] The Sky Planter (resembling an upside down pot) uses an internal reservoir system that feeds water directly to the roots without leaks or evaporation, and uses 90% less water.

Interior living walls: There exist many attractive interior space dividers that support plants for cleaning air. Living walls have also been combined with mechanical ventilation systems. For example, a three story high living wall, located in the main lobby in Queens University in Canada, is a natural air filter which removes VOCs and CO_2 as air passes through the wall into the office spaces via the mechanical system.[47]

Green scaffolding: Wrapping old buildings in multifunctional ecosystems in ecospheres has been suggested.[48] The modules or ecospheres that variously heat, cool, ventilate, treat waste and produce food and even support small endangered ecosystems. They are supported by triangular truss structures. The same concept can apply to new buildings, as proposed for the Australian National Sustainability Initiative.[49]

3.8 Water treatment

Water vapor is part of a natural cycle, so extracting water from the air, especially in humid environments, does not damage local ecosystems or permanently alienate water resources. Ironically, in Brisbane, Australia, humidity is a major cause of discomfort, even in times of severe water restrictions. However, water could be captured from the air using simply evaporation techniques in combination with other building elements.

Watermill: The Watermill is a product that avoids fungi, cleans the air and makes water. This water is collected from the air, passed through a specialized carbon filter and then exposed to an ultraviolet sterilizer, to eliminate bacteria. The WaterMill reputedly produces 12 litres (13 quarts) of water per day, and mounts to the exterior of the home.[50]

Watercones: 6,000 die each year due to unsafe water. Watercones are a solar-powered water purified and desalinator which generates freshwater from dirty water.[51] It and similar designs collect clean water through evaporation in a transparent plastic or glass facing the sun over an open container of dirty water. It could be upscaled and integrated with building structures.

Desert Cubes: Faecal bacteria digest uric proteins to give off toxic, smelly ammonia-based gases which become airborne when toilets are flushed and grow on bathroom surfaces. Desert Cubes use microbes to interfere with the bacterial digestion that produces odours by binding with the solids found in urine (from Eco-specifier).[52] Apparently, it improves the health of the sewage system downstream as well.

3.9 Sludge and sewage treatment

Living Machines, a concept developed by John Todd, are a natural form of purification process in which water is sent through a chain of ecosystems. Living Machines can treat sewage and sludge from factories, buildings or whole neighborhoods. On the same principle, restorers are floating ecologies on rafts to clean lakes, factory waste or even sewage canals in developing cities. They can improve the quality of reservoirs and local ponds.

The Living Machine: Living machines are a train of ecosystems. The first tank has algae and microorganisms which decompose the organic waste, and aquatic plants which take up the remaining nutrients.[53] The next tank can be an artificial marsh of sand, gravel, and reeds to filter out remaining organic waste and algae. The next tank can contain snails and zooplankton that consume the remaining microorganisms. Fish then eat these and, in turn, can be sold for bait. Additional steps can be taken to ensure clean water, such as exposing the water to ultraviolet light.

Building integrated Living Machines: The 60L building, the Australian Conservation Foundation's retrofitted building in Melbourne, displays a living Machine in its lobby.[54] Components of the water supply system include rainwater collection and use, efficient water supply appliances, waterless urinals, on-site treatment of wastewater and sewage and recycling of treated waste water for toilet flushing and irrigation of landscape features.

River rehabilitation: Vetiver is a non-invasive, clumping grass with an extensive root system that treats contaminated water and tolerates high levels of heavy metals and agricultural chemicals.[55] When planted in narrow hedgerows, its extensive and deep root system holds soil together and acts a filter for contaminated water. To assist in de-contaminating waterways, Vetiver could also be placed on floating bamboo in rivers.

3.10 Lighting and views

Natural lighting, especially in combination with good ventilation and views, etc, reduce sick leave, absenteeism and workers' compensation claims. Viewing gardens in hospitals reduce stress, medication, recovery time and surgical complications. Built environments like gardens can be preventative medicine. [56]

Light-transmitting concrete: Litracon is a product with optical fibers (flexible light pipes) running through poured prefabricated concrete blocks or panels to transmit light from one side to the other.[57] The optical fibers can transmit light to 50 feet without significantly affecting the structural capabilities of the concrete. Thus, daylighting is not limited to narrow or light weight structures.

Blight Blinds: Designed by Vincent Gerkens, Blight combines solar collectors with Venetian blinds that follow the course of the sun to catch maximum energy.[58] They can double as lamps without any need of additional electricity supply.

Hybrid solar lighting: A tracker system on a roof moves with the sun, collecting light into a beam that focuses the sunlight onto optical fibers connected to hybrid light fixtures that have special diffusion rods that spread out the light in all directions. One collector powers about eight hybrid light fixtures which can illuminate a 1,000 sq ft.[59]

3.11 Heating and cooling

Energy and greenhouse emissions in urban buildings can dwarf other sources, depending on who measures what, when and where. Passive solar design is very important, as it can replace other sources of energy for heating and cooling homes and buildings. However, many books about it have been available for at least thirty five years, so the basic forms of passive solar design are not discussed here. A couple of less familiar passive design concepts are listed instead.

Wind towers and shower towers: In hot climates, wind towers can scoop air into the building where it is cooled by water through evaporative cooling. This passive cooling system was used in ancient buildings in the desert. Shower towers use falling water in a tube to draw air into the building, as the falling water displaces the air. The water cools the air through evaporation as it falls. The cooled air can then be drawn into the building at floor level or in ducts.[60]

Solar stacks and solar cores: Sometimes called 'solar chimneys', these use the stack effect to draw heat out of the building through a vent in a dark tower that exceeds the height of the roof. This works using convection, as hot air rises and dark objects absorb heat. This can be combined with rock storage for warm or cool air, as proposed in the Solar Core.[61]

Reverse Trombe wall: Conventional Trombe walls create an air space between a masonry wall and exterior window. The heated air is can be circulated by convection. In summer, the glass is shaded. A 'reverse' Trombe wall would put a glass frame over an existing masonry wall, with vents drilled through the wall at the top and bottom. For non-masonry walls, rock stacks (to store heat) could be inserted between the existing wall and a glazed frame, in a wire frame or gabion. [62] This would preserve existing views.

3.12 Electricity production

Developments in wind and solar energy are extremely rapid, and the rise of oil and coal prices are leveling the playing field. Solar and wind energy are still expensive, but not when the externality costs of fossil fuels are weighed into the equations. Fossil fuels have no payback period at all. Their production entails huge amounts of embodied energy.

Urban wind: Irregular urban wind in specific places can magnify the wind effect. Irregular wind can be a problem, but vertical shaft wind generators are relatively good with intermittent wind conditions. The 'Mag-Wind' is an example.[63] A roof with a 10 foot vertical rise and a 20% angle will provide nearly a 200% increase in the amount of wind energy that is available.[64] Wind energy can also be accelerated by building design, as in the Bahrain World Trade Centre, where three wind turbines are expected to provide 10-15% of the power for both towers, operating 50% of the time.[65]

Power glass: There are many new products that promise to generate solar electricity using a transparent solar cell which turns sunlight into electricity along the lines of the photosynthesis process of plants.[66] The cells produce electricity when electrons bound within atoms are liberated by incoming light. Thin semi-transparent coatings and films can be fixed on glass or other transparent products. PowerSheet is as thin as a layer of paint and transfers sunlight to power cheaply.[67]

Power foil: Nanotechnology is being used to print PV cells directly onto flexible film or foil sheets. These flexible films, created from monocrystalline silicon material, may be transferred to an existing façade or other surface. The manufacturer can change the spacing of the cells for different levels of transparency (versus solar intake). For example, window transparency can be increased where there is little sunlight.

Crowd farming: Flooring has been used to collect kinetic energy in several nightclubs in Europe. A train station in Tokyo will use crowd farming to power ticket gates and display systems, and is expected to obtain1,4000kw per day. A revolving door (Fluxxlab), can also be used to capture energy and can bridges.[68] Similarly exer-cycles can be connected to computers for supplementary power while encouraging healthy workplaces.

3.13 Fire and flood prevention

Often after a fire, homes are bulldozed and rebuilt in the same landscape. Fire prevention strategies are generally costly and ineffective, such as designing out places where embers can collect by avoiding eaves or complex roofs. Instead, landscaping for recreational facilities with multi-purpose fire prevention structures and water storage can add value to the public estate and the local ecosystem. Likewise, cities can be retrofitted to minimize flood damage rather than building expensive barriers that will exacerbate impacts in case of a larger flood.

Water storage walls: Self-supporting modular system for water storage, and free-standing green walls can be retrofitted internally or externally in public spaces at the perimeter of towns to fight bush fires.[69] The storage and irrigation systems can be combined with sprays that activate in case of fire, and they can be used as fire barriers to slow down smaller fires and protect emergency shelters.

Floating homes: Sea levels are projected to rise up to 3 feet by 2100. 'For every foot of sea level rise we can expect about 100 feet of coastal flooding'.[70] Dutch canals which have been built on solid ground but without foundations. They are designed to float by being constructed from lightweight timber and a hollow concrete base similar to a boat hull.[71] A vertical guidance system to keep them in place.

Flood mitigation: Where homes in flood prone areas cannot be moved to suitable locations, they can be retrofitted with pontoons, so that they can float in a flood (or store water in a drought).[72] The 'Amphibious' foundation system would allow a house to rise in the event of a flood, having flexible utility lines to allow floating.[73] Alternatively, the 'Neptune' flood defense system is a rubber skirt fixed around the building that lifts up in severe weather.

3.14 Earthquake and cyclone proofing

Earthquakes and cyclones kill thousands of people each year. If a value were placed on human life, it would cost relatively little to reinforce buildings to prevent cyclone and earthquake damage – or at least increase the likelihood of the survival of more building occupants. The cost and risks of salvaging communities after the fact is seldom compared to the costs of prevention. Green scaffolding, which combines a structure with food production, heating and cooling, could pay for or offset the cost of reinforcing buildings.

Infrastructure reinforcement: Large-scale infrastructure can be made more resistant to seismic activity. For example, Carbon Fiber Reinforced Polymer (CFRP) can be wrapped around circular reinforced concrete columns to make them more earthquake proof (or perhaps even flood proof.[74] Cables can also be used to reinforce homes to reduce damage and death from earthquakes at relatively low cost.

Masonry reinforcement: In poor regions, mud huts and large masonry buildings can be retrofitted with bamboo to reduce earthquake damage for long enough to allow evacuation. Using bamboo, many small cross braces are be required to increase the amount of support points on the structure and increase its rigidity.[75] Chicken wire mesh can be combined with bamboo to reduce the damage caused by collapse as well.

Glass protection: Safety film products are available which meet the same break-safe requirements as tempered safety glass. They can hold glass shards together in strong winds, to prevent sharp, broken glass from injuring people. Custom-designed 'nets' for covering homes in cyclones is also a possibility.[76]

3.15 Biodiversity protection

Urban consolidation does not really address the problem of existing sprawl. It only accommodates further growth in confined areas. While the land area occupied by cities is relatively small, for historical reasons cities often occupy the most valuable land in ecological as well as economic terms. Cities and highways also divide and destroy ecosystems. Co-existence of human and ecosystems will be necessary in both urban and rural areas.

Nature corridors: Train corridors can be eyesores and reduce property values due to perceptions of crime, noise pollution and visual intrusion. However, some existing railways are being converted to green corridors.[77] New and retrofitted tram developments in several European cities now have lawns. Of course, lawns need to be converted to native ground covers that do not need mowing or toxic fertilizers. Islands can be created over freeways for parks or public facilities even in cities. They can provide safe crossings for animals whose habitats and migration cycles have been interrupted by large scale infrastructure.

Bio-tunnels: Some have proposed railways or freeways to be enveloped in modular and continuous green 'tunnel' envelopes. Utilizing a lightweight frame, the roof and walls of such tunnels could act as water collectors and filters, as well as serve acoustic functions.[78] A modular system (based on road barriers) can increase the surface area available for ecological functions by using vertical space. Each module can house a grid of snap-in units containing planting media.

Green alleys: Bioswales and raingardens can be combined with nature corridors in alleys. A proposal called Eden Bio features terraced houses arranged along pedestrian alleys set within densely-planted gardens.[79] The upper level units will be reached by external timber gantries and staircases enclosed in greenery. These turn alleys into a living walls that are integrated with stairwells.

3.16 Transport

Transport is a major environmental problem, and is also a major cause of shortened life spans. The total human toll from cars has been estimated at 250 million deaths. Individual car owners do not pay the full costs of the externalities of driving or the benefits they enjoy from public transport (like decongestion and cleaner air). Ironically, when a shark, wasp or jellyfish kills someone, there is usually a call to eliminate them entirely. Likewise, when a driver runs into a tree, there is often a call to chop down the trees.

Bikedispenser: The bikedispenser is a fully automated bicycle rental station.[80] It is a solution for integrating the bike into the daily car, bus or train commute and reducing the space requirements of parked bikes. Similarly, a car share program has been suggested to reduce car ownership. The embodied energy of cars is often eclipsed by worries about fuel. To use the car, one simply swipes a zipcard which pays for the travel costs and a system fee.[81]

Retrofitting Rickshaws: Much of the air and noise pollution in cities in India and China are caused by inefficient, petrol-powered, rickshaws. Lead acid batteries are also a big problem. In India there are close to 1.5 million three wheelers.[82] These rickshaws could be retrofitted, instead of replaced with, solar-powered electric bike technology.[83] Electric bikes also allow older or less fit people to exercise while commuting without overdoing it.

Personal Rapid Transport (PRT): A new city Masdar, in Abu Dhabi, plans to have a solar powered PRT system with tree-lined paths.[84] It will have a fleet of solar powered electric vehicles that carry up to 6 passengers between any of the 1500 transit stops. This concept could be used in central business districts accessed from parking areas at the outskirts of a city until such time as small electric vehicles replace fossil fueled cars entirely.

4. Conclusion

In summary, there are a range of eco-solutions available for all levels of the built environment from products to bioregions. Some reduce pollution and waste, but others potentially add value to the ecological base and public estate. They range from high to low technology, from small to large scale, and can be designed to suit widely divergent design preferences. Several could be combined and/or applied on more than one scale at once. Some go beyond 'closed loop' systems to eco-productive ones. In synergistic combinations with passive solar retrofits, these eco-solutions could potentially have net positive ecological impacts over the development's lifespan.

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